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Canadian Wave Climate Study: Organization and Operation

J.R. Wilson and W.F. Baird

Marine Sciences and Information Directorate
Department of Fisheries and Oceans
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Station locations in marine and inland waters at which wave observations have been made.

CONTENTS

ABSTRACT

The Canadian Wave Climate Study (Baird et al. 1971) was established in 1968. Since that time data have been collected at about 200 locations in marine and inland waters around Canada. A standard analysis procedure and a set of data presentations useful to design engineers have been developed and are discussed. The instrumentation employed, its reliability and operational characteristics are also discussed.

RÉSUMÉ

Le service canadien des Études des vagues (Baird et coll. 1971) a été créé en 1968. Depuis lors, on a recueilli des données en 200 points environ des eaux maritimes et intérieures du Canada. Le document examine la procédure normalisée d'analyse et une série de présentations de données, utiles aux ingénieurs d'études, qui ont été mises au point. Les instruments utilisés, leur fiabilité et leurs caractéristiques opérationnelles sont aussi étudiées.

1. DEMAND FOR WAVE DATA

1.1 Requirements for wave data

The Wave Climate Study was established to provide information for the design of marine facilities such as deep water ports, breakwaters, offshore structures, etc. The study was considered complimentary to other wave projects being done in Canada, such as the work being carried out at the Bedford Institute and at the Atmospheric Environment Service using ship reports of visually-observed waves. The present study was addressed to site-specific engineering-quality data as opposed to the investigation of sea-state and interannual variability over large areas of ocean.

Initially it was proposed that areas with similar exposures be chosen and measurements made to establish a "wave climate" for each area. In all 32 locations were proposed to establish the "wave climate" for the coasts of Canada.

This concept was recognized as inappropriate at an early date. Wave measurements taken at a location in deeper water can generally not be used to predict the wave climate in shallow and partially protected coastal locations because of the complexity of the interaction of the waves with the bottom topography. Consequently the focus of the study was soon shifted to making measurements at the location of the planned facility. During the early years of the study some other requirements for wave data emerged.

The first of these other requirements was for a continuation at a reduced level of the gathering of general coverage wave climate data. It is useful, for example, to have limited coverage at some locations where marine activity is heavy, for calibrating wind-wave hindcast models and to give some limited general information on wave statistics, wave steepness, storm profiles, etc.

The second requirement was for wave data in the offshore areas where hydrocarbon exploration was proceeding. Since drilling permits and designs have to be reviewed by the Canadian government and as one of the criteria considered is the ability of the equipment to survive and operate in the conditions encountered at the site, it was felt that every opportunity to obtain wave data should be pursued. To these ends the study has entered into various joint programs with drilling operators. The study supplies the wave recording equipment, the operators install, maintain and operate the equipment and the study undertakes to do the data analysis and provide a copy of the analysis to the operators. A condition of this type of cooperative program is that the data are immediately in the public domain. As a result, the study has substantially increased wave data holding for the east coast of Canada and the Beaufort Sea.

Finally, it was considered important that at a few selected locations, measurements should be made to permit some study of long-term wave statistics and to establish the relative severity of storm conditions in a particular year. Typically 9 to 10 years of data are now available at selected locations on both the east and west coasts of Canada.

For many problems in the design of marine facilities wave direction is also an important parameter. For example, in the layout of berths within a harbour the direction of the waves impinging on the ships cannot be ignored. In problems involving the transport of sediments direction is obviously critical.

It was, at the time this study commenced, beyond the state of the art to routinely collect and analyse directional wave data. The measurements have therefore been confined to one dimensional wave data. In many design problems directional information is inferred from hindcast techniques using wind data from either a nearby meteorological station or from winds obtained from the synoptic weather maps issued by the Canadian Atmospheric Environment Service.

In other cases direction can be inferred from the physical boundaries of the harbour entrance, for example, and the topographical features inside the harbour.

At the moment it appears that equipment capable of routinely measuring wave direction may be coming available and the study is taking another look at the technology with the goal of beginning routine directional measurements at some sites.

1.2 Uses of the data

One of the most important uses of the data is the one for which the study was established; the design of marine facilities. During the planning stages for a new harbour or marine terminal measurements at the site are carried out for the ice free part of at least one year. A 20-minute wave record is taken every three hours for the duration of the measurements and a characteristic wave height and peak period of the spectrum are computed for each record. For some projects more than one recorder may be installed. For example, one instrument may be installed in the deep water approaches to a facility and one or more other instruments at the proposed site or sites of specific construction. These data may then be used for several purposes.

Design criteria for extreme events are normally established by extreme value and storm profile analyses using available wind data. An established design storm is then hindcast into wave data using a model that has been previously "tuned" by comparing the recorded wave data with wave data hindcast using corresponding wind data.

The percentages of the time that wave heights or periods exceed given values in an average year, may be obtained directly from the recorded data, sometimes modified with results from the hindcast analysis. This data is then used to determine the optimum lengths and locations of protective structures such that wave agitation at the areas of interest does not exceed established limits. The same data also provides information on probable downtime during construction, i.e. times that tugs other service boats and dredges will be inoperative due to wave conditions. Material losses or damage during construction due to erosion by wave action can also be estimated. Oil companies use the wave climate statistics to estimate down time at the drilling sites and the probable times that service boats will be inoperative.

During the design stage for a marine facility the Canadian Department of Public Works will often make extensive use of physical scale models. Figure 1 is one such model of a harbour constructed at the National Research Council Hydraulics Laboratory. Measured wave periods and heights, suitably scaled, are input to the model and the resulting wave characteristics at important points in the harbour can be observed. The proposed breakwater length and orientation can then be altered until the wave effects found inside are acceptable. The model is also used to examine wave induced currents and appropriate openings are designed into the breakwater to prevent areas of stagnant water.

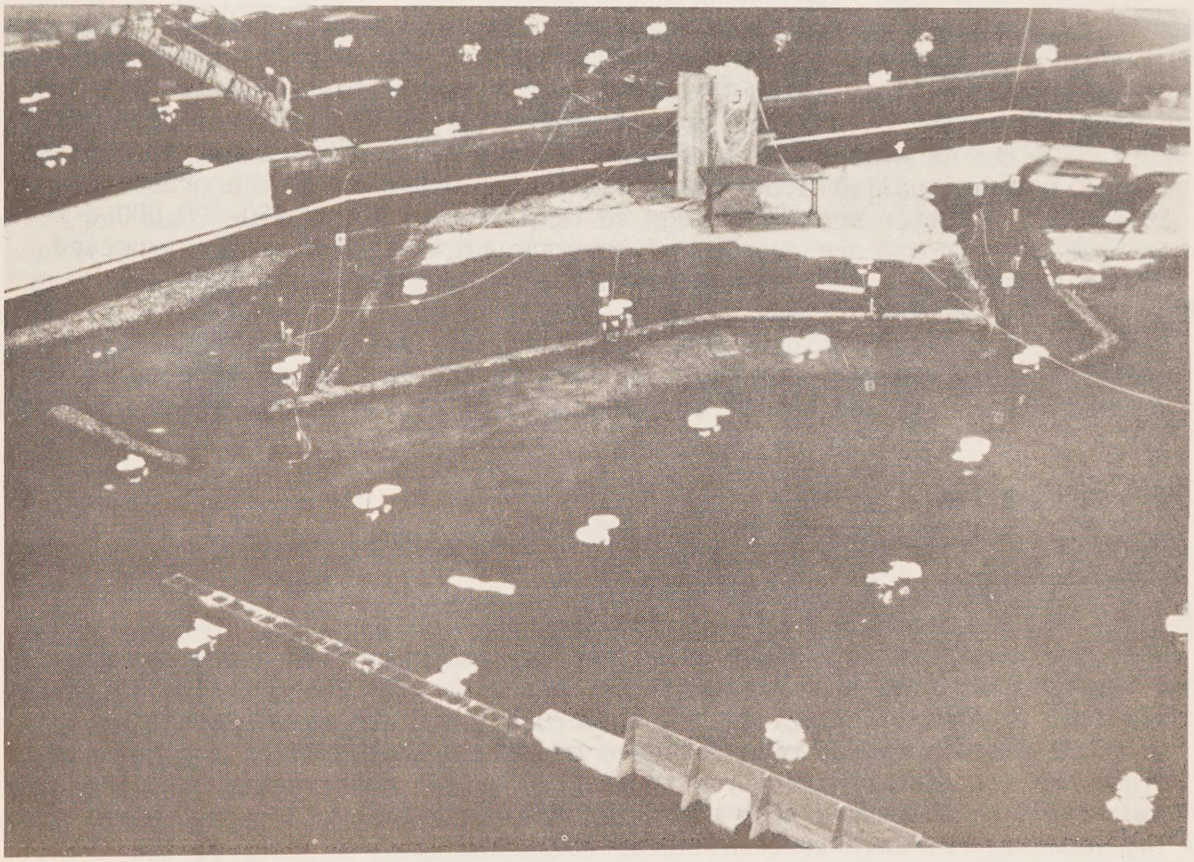


Fig. 1. Scaled model of a harbour (Oshawa Harbour) for study of waves prior to design and construction (courtesy of C. Glodowski of Department of Public Works).

Physical models are also used in wave tanks to determine suitable cross sections for structures. The design wave, arrived at from the measurements and hindcast analysis and suitably scaled, is input to the wave generator. Scale models of the proposed structure are erected and the effects of the waves are directly observed.

Other uses of the data collected in the program include its consideration in the licencing of ships or other marine vehicles to operate in certain areas, its use in estimating sea clutter on long range radars, and its use as input to real time wave forecasting models to give a few examples. The program has also supported a number of oceanographic experiments on an "ad hoc" basis and has provided ground truthing for remotely sensed waves and for wave data hindcast from winds.

1.3 Cost justification

Cost benefit analyses for a program such as the Wave Climate Study are difficult to provide. It costs about $15,000 to $18,000 for the Canadian Government to collect and analyse one year's wave climate data. This is equivalent to the cost of 0.5 meters of breakwater at a typical deep water port. If the length of a breakwater could be reduced by 15 meters because wave data were available the potential saving would be of the order of $500,000. A cutter suction dredge costs of the order of $60-$80,000 a week to operate. To pay one quarter of this amount to determine the expected down time during a dredging contract is a sound investment.

When one also considers the possibility of loss of life and environmental damage from accidents associated with the failure of structures it becomes clear that the design engineer must be provided with these wave data.

2. ORGANIZATION

2.1 Number of stations maintained

The Wave Climate Study has for the past five years operated at a level of about 20 recording stations per year. Of these typically, three are long term stations maintained to obtain long-term wave statistics, six to eight are associated with offshore petroleum exploration, another six to eight are associated directly with planned marine construction and the other four might be concerned with scientific experiments or surveys. A map showing locations of wave stations occupied by the study appears as the frontispiece of this report.

2.2 Manpower requirements

The study utilizes a four man field team. In addition about 1½ man years of effort are expended in analysing and making the data available. The field team has a number of functions. Its major responsibility is the maintenance of sufficient equipment in an operational state and "ready on the shelf" to meet the requirements for wave measurements each year. This includes refurbishing, repair and calibration of the various wave sensors and recording equipment in use in the study. The maintenance of many of the stations is contracted to local industry or is carried out by drilling

companies, site engineers, or regional scientific and tecnical staff in the case of cooperative programs. The field team has the responsibility of training new contractors and the various other people who install, operate and maintain the wave equipment. They also have the responsibility of maintaining the equipment at stations where local servicing could not be arranged.

2.3 Computer usage

Computer usage in the project is confined to two small special-purpose computer systems and a large general-purpose system. The first special-purpose system was designed and built "in-house" to digitize tapes recorded in the field and to produce a standard digital tape for later analysis. In addition to digitizing the FM signal recorded on the magnetic tapes, this system takes out the wow and flutter introduced into the signal by the mechanical imperfections inherent in the field tape recorders and also corrects for any problems associated with line frequency fluctuations for generator supplied power. All digital analyses are carried out on a large general purpose computer. The second special-purpose system used in the data handling is an off-line data display system used to plot wave spectra for quality control purposes. The quality control procedures are described in more detail in section 4.

3. WAVE SENSORS

3.1 Some considerations in selecting the wave sensor

The study employs a number of instruments for routine wave measurements. Wave staffs, pressure sensors or accelerometer buoys are selected for a specific project depending on the logistics of the situation. In most circumstances the Waverider accelerometer buoy is used provided current velocities are not excessive, interference from shipping or fishing is not expected, and there is sufficient area for the buoy to freely move.

Drawbacks of the Waverider include its vulnerability to collision with boats and other floating objects and to radio transmission interference. In situations where the instrumentation is to be located in an existing harbour where space is limited a wave staff will be used. If a suitable mounting for the wave staff is not available a pressure sensor will be employed.

Drawbacks of the pressure sensor include the attenuation of the pressure signal with depth and increasing wave frequency and the requirement for a cable to the sensor. Drawbacks of the wave staff include corrosion and fouling problems, vulnerability to floating objects and the requirement for a surface piercing structure on which to mount the sensor.

3.2 Performance and calibration of the Waverider buoy

The Waverider buoy has become the standard instrument of the study because of its accuracy, reliability and ease of handling. A further advantage of the Waverider is that it either obviously fails or it functions correctly. In any comparison with other instrumentation which has been done by the study the agreement has been within 3 to 5% for the computed value of significant wave height.

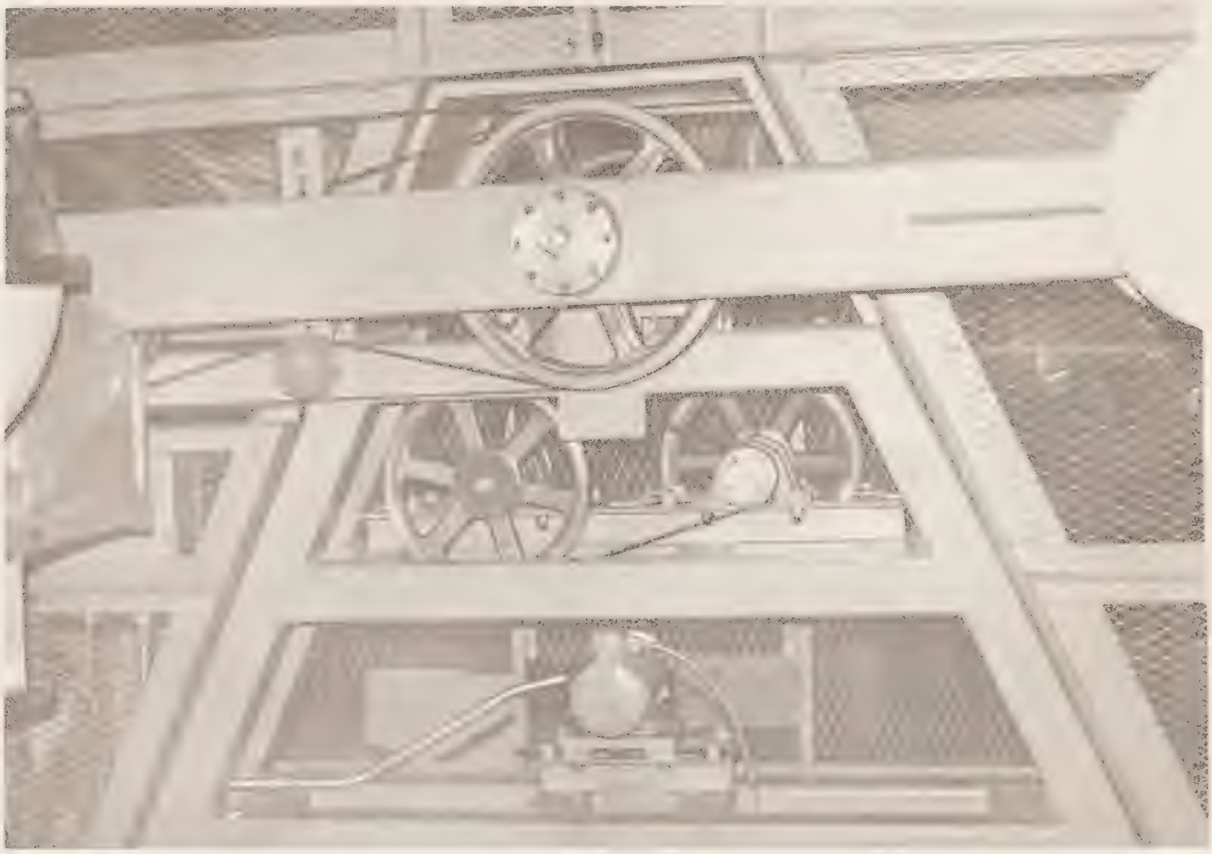
It is also standard practice in the study to verify the calibration of each buoy before installation and immediately after removal from a site. This is accomplished using a device (see Figure 2) which physically carries the buoy in a 2 meter diameter circle at any number of constant selectable frequencies. The output of the buoy is recorded exactly as in the field situation and the data is processed through the same programs as the field data. This provides a check not only of the buoy calibration but also of the data analysis hardware and software. The output from a buoy calibration analysis is shown in Figure 3. Figure 3a shows the deviation in percent from the true vertical travel of 2 meters as a function of period of rotation of the calibrator. The corrections at the low and high frequency ends of the spectrum due to the low frequency cut-off of the integrators and the high frequency characteristic of the Waverider phaselock system have been applied. Figure 3b shows the energy spectrum for a typical buoy oscillated with a period of 4.9 seconds. The spectrum is quite narrow and shows little energy other than at the main peak. Figure 3c shows the displacement of the buoy as a function of time. This diagram is used to detect low frequency drift which can occur if the accelerometer suspension is slightly damaged.

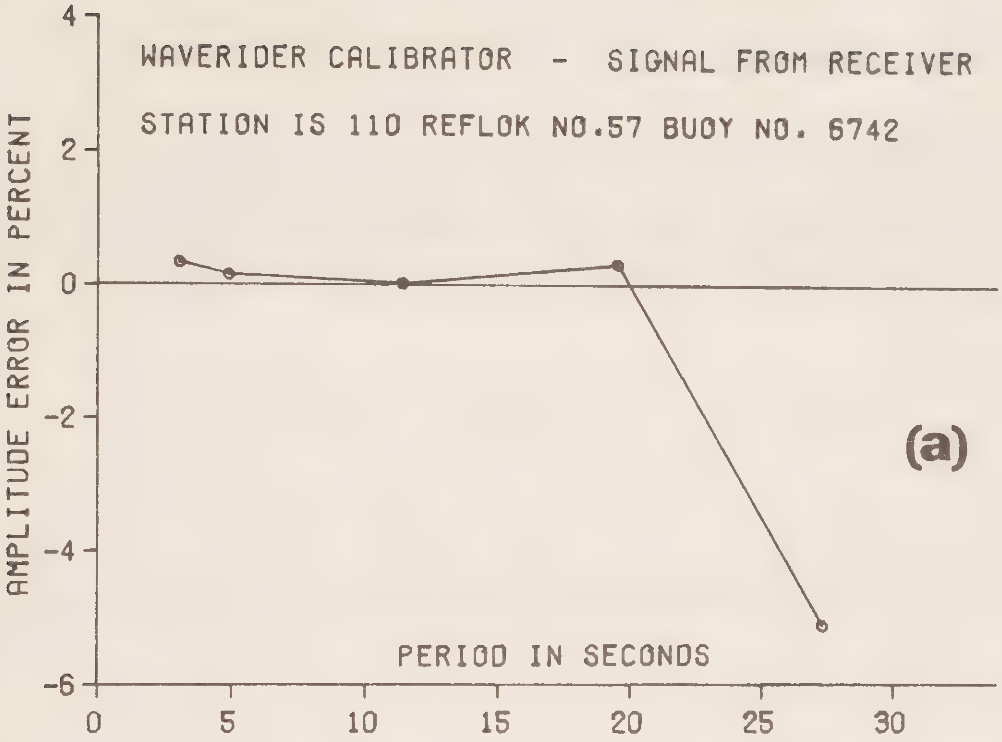
This procedure has resulted in the checking of buoy performance in this manner more than 275 times in the past few years. In approximately 90% of the tests the buoy performance was within 3% of the specified calibration. In most of the other 10% of the cases a simple inspection of a wave record or spectrum would have indicated the instrument was faulty. In only a very few cases was a buoy found to be giving erroneous amplitude information without the record being obviously suspect. This was due to an increase in accelerometer cell conductivity brought on by aging of the fluid. A hardware fix is available and is being applied to all the buoys.

The Waverider has also proved easy to moor from a small boat. Mooring problems have been confined to abrasion of the wire rope portion of the mooring on the bottom and occasional failure of swivels or other components due to corrosion. The problem with abrasion on the bottom was solved by beading the cable with air compressor hose. The problem with corrosion of swivels was solved by changing manufacturers.

Another problem had to do with fouling of the buoy in warmer waters. An anti-fouling paint system has been found to solve this problem. Cold weather problems have been confined to icing of the antenna resulting in occasional loss of transmission.

Fig. 2. The Waverider (buoy) calibrator (developed by the Marine Environmental Data Service) is a variable speed mechanical oscillator capable of rotating a Waverider in a fixed plane at a number of selectable fixed frequencies.





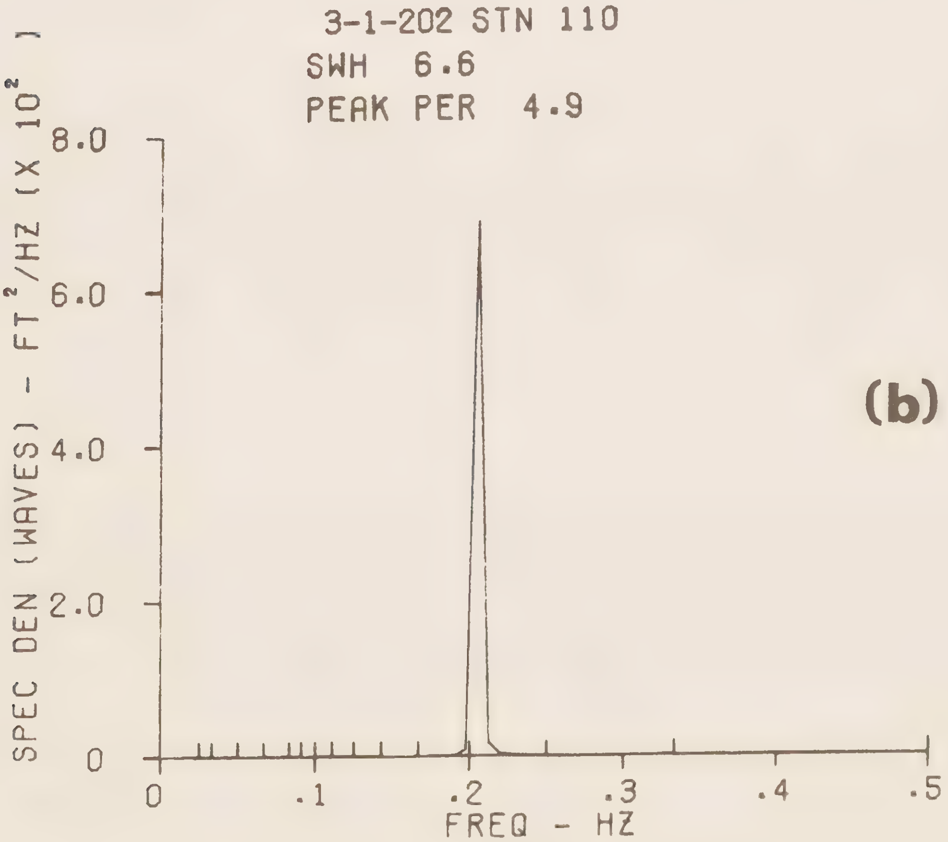
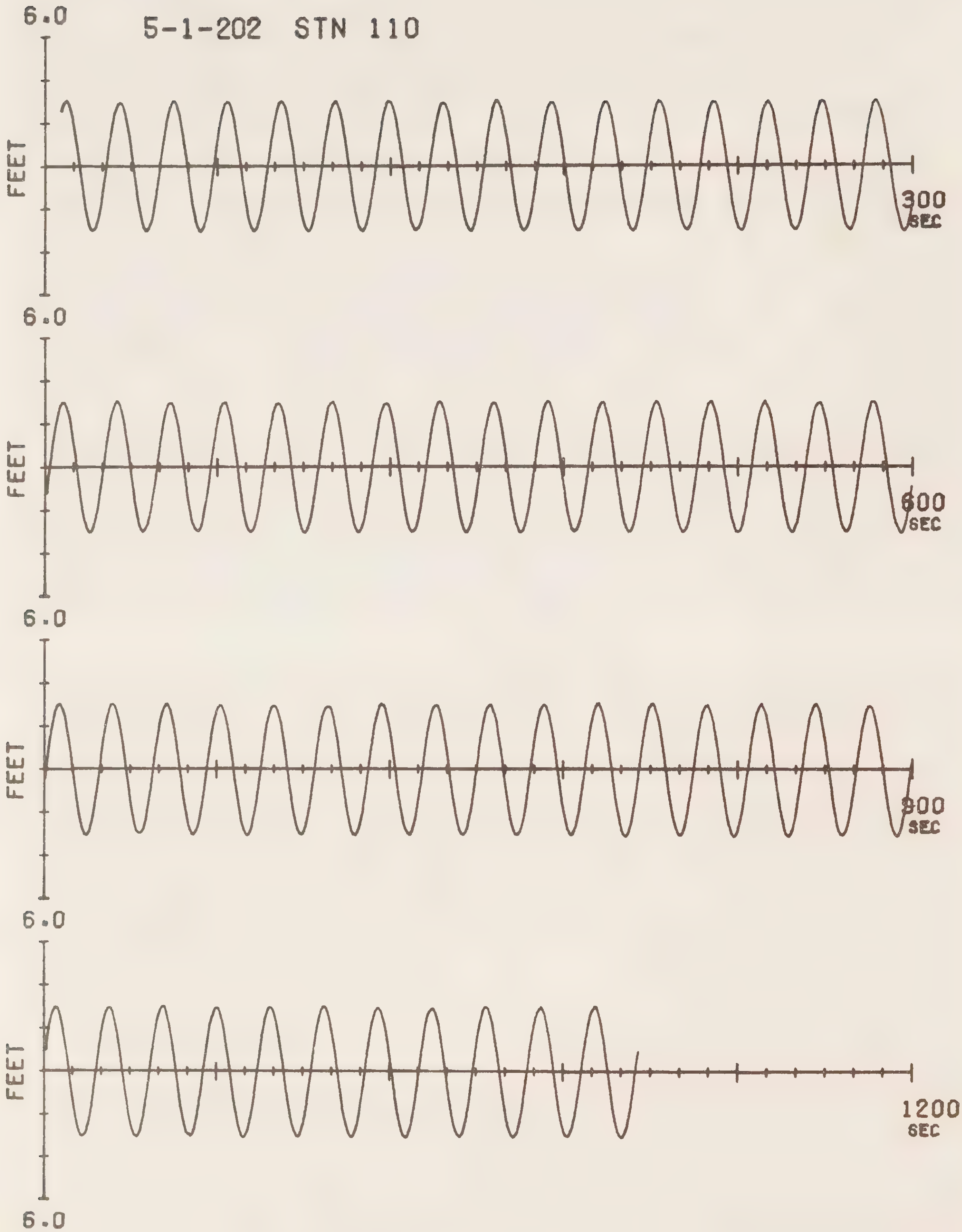


Fig. 3. Output of the Waverider during calibration. (a) Deviation (b) Spectrum and (c) Displacement.


5-1-202 STN 110
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(C)

4. DATA CONTROL AND ANALYSIS

Two decisions made in establishing the analysis system for the study were to record on magnetic tape for machine processing and to adopt a Fourier analysis of each 20 minute wave record as the standard analysis technique. The Fourier analysis, which provides the wave energy spectrum, is useful because many wave sensors require a frequency dependent response correction. Secondly, a Fourier analysis using the fast Fourier transform technique is economical.

Field recording of the data is automatic except for the requirement to turn over a tape after four days of recording and to mount a new tape after eight days. The wave signal is recorded as an FM signal and a constant frequency oscillator signal is recorded on the second channel of a standard stereo tape deck. Absence of the oscillator signal is used by the analysis system to indicate equipment malfunction. The oscillator signal is also used to remove power line frequency fluctuations or mechanical tape recorder speed fluctuations from the data. Administrative data including time, date and station identification are also needed.

Data handling begins with a scan of the tapes immediately they arrive to detect major equipment failure at an early date. The tapes are then digitized and the spectrum analysis is carried out. This yields characteristic wave height, peak period and power spectrum information.

Quality control of the data proceeds as soon as the spectrum computation is completed. A digital magnetic tape is produced containing the spectrum for each 20 minute record. This tape is processed on an off-line computer system which displays each spectrum diagram for viewing on an oscilloscope display. Instrument malfunction or radio interference is easily detectable and these 20 minute records are marked in the file. If required, a surface elevation trace can be viewed on the oscilloscope in making the decision to use or mark the record. The final phase of quality control consists of producing the standard set of statistical summaries and looking for outlying points. Records corresponding to outlying points are reviewed a second time. In subsequent analyses the records marked in the file as erroneous or questionable are not used.

All data products are produced from the variance spectrum analysis and deal with the characteristic or significant wave height obtained from the zeroth moment of the spectrum and the peak period obtained from the frequency of the maximum spectral density. Occasionally wave by wave analyses are undertaken for special purposes such as studies of wave grouping. Wave by wave analyses are expensive as it generally requires digital band pass filtering of the signal prior to picking off the crests, troughs and zero crossings.

5. DATA REPORTS

The standard data products and reports available from the system are shown in Figures 4 to 9 and in Table 1. Figure 4 is a "scatter diagram"

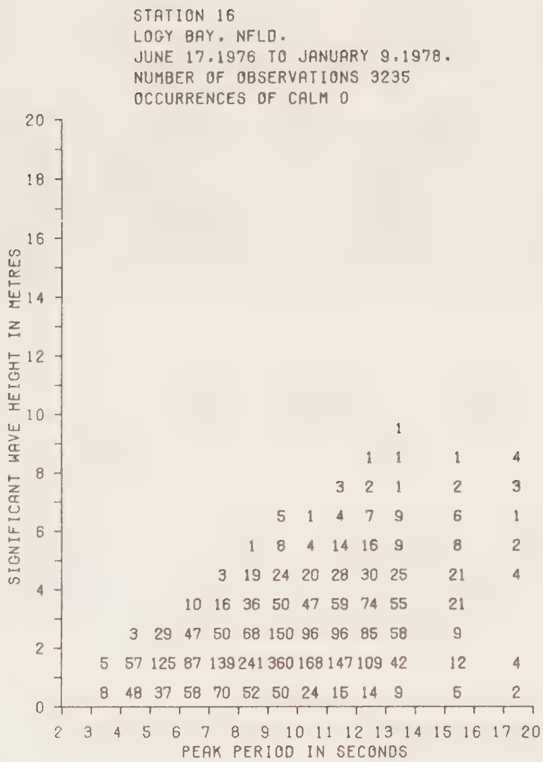

Fig. 4. Scatter diagram.

This diagram shows the number of occurrences of various characteristic wave heights with various peak periods. The characteristic wave height for each wave record is computed as four times the square root of the area under the variance spectrum of the water surface elevation for the 20 minute record. The peak period is defined as the inverse of the frequency at which the maximum spectral density occurred.

The period of time over which the observations were made is annotated at the top of the diagram along with the number of observations from which the diagram was prepared. The "Occurrences of Calm" figure represents the number of records for which the characteristic wave height was less than 15 cm. For wave heights less than 15 cm, signal to noise ratio problems essentially render the period indeterminate.

Figure 5 shows a typical peak-period histogram. This histogram shows the percentage of wave records for which the peak-period was in each of the indicated ranges. The peak period for each 20 minute record is defined as the inverse of the frequency at which the maximum spectral density occurred. The annotations on the figure give the same information as in Fig. 4.

Figure 6 shows a typical exceedence diagram. This diagram shows the observed percentage of the 20 minute wave records for which the characteristic wave height exceeded a certain value. The characteristic wave height for

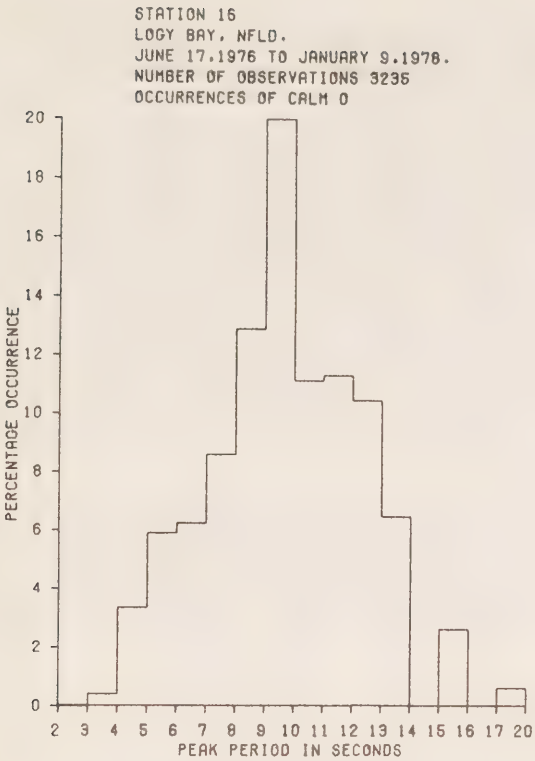

Fig. 5. An example of a typical peak-period histogram.

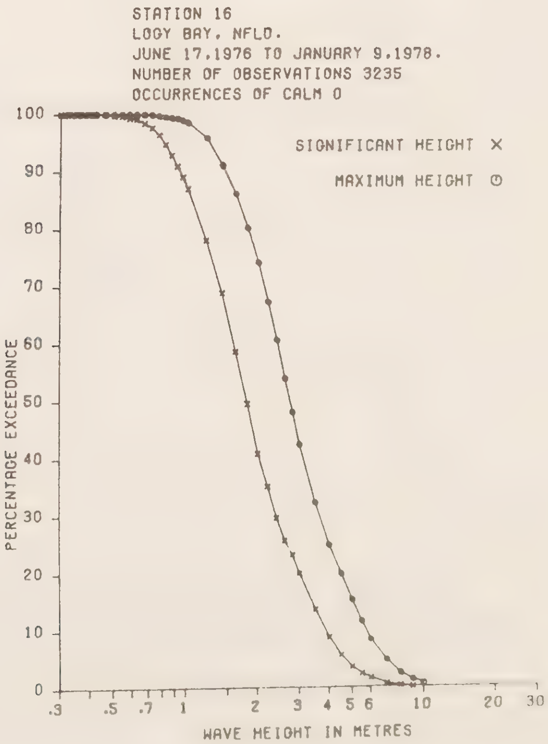

Fig. 6. An example of a typical exceedence diagram.

each wave record is computed as four times the square root of the area under the variance spectrum of the water surface elevation.

The curve labelled maximum should be interpreted as the exceedence curve for the most probable maximum wave in a twenty-minute period. This wave was computed using the Longuet-Higgins (1952) theory for the statistical distribution of the heights of sea waves for a narrow band of frequencies. The most probable maximum wave is, according to this theory, derivable from the characteristic wave height and the number of waves in the record. The number of waves was obtained by dividing the length of the record time (twenty-minutes) by the peak period of the spectrum. The peak period for each wave record is defined as the inverse of the frequency at which the maximum spectral density occurred. The annotations on the figure give the same information as in Fig. 4.

Figure 7 is a graph of characteristic wave height plotted as a function of time for a month. The significant wave height has been computed for a 20 minute wave record every three hours. It is defined as four times the square root of the area under the variance spectrum of the water surface elevation. The units are meters.

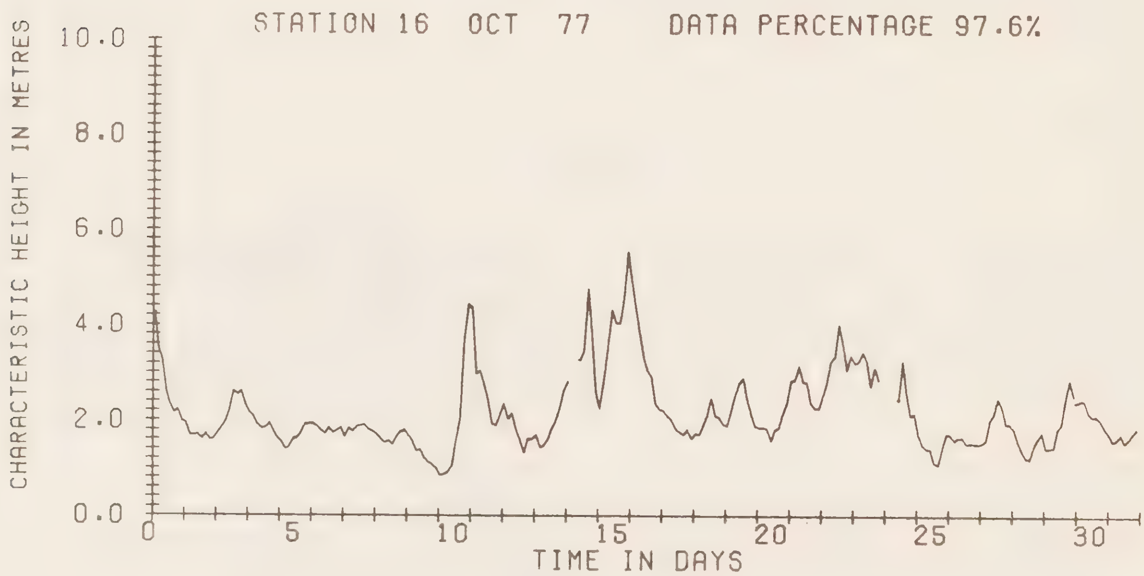

Fig. 7. Characteristic wave height over the period of one month.

When the interval between successive wave records is the expected three hours, linear interpolation of the graph is carried out to produce a continuous trace. Gaps in the trace indicate missing records due to failure of the recording equipment or to failure of the recorded data to pass the necessary quality control checks.

Figure 8 is a spectrum diagram. It shows the variance spectral density of the water surface elevation as a function of frequency. The densities are computed at approximately 60 discrete values of frequency between 0.05 and 0.5 Hz using the fast Fourier transform algorithm. Each twenty-minute wave record is broken up into several blocks of 1024 data points. The number of such blocks will be determined by the digital sampling frequency. The final value at each frequency is the average of the densities at the frequency over all the blocks. For certain stations on the west coast the range of frequencies is extended to include up to 30 second period waves.

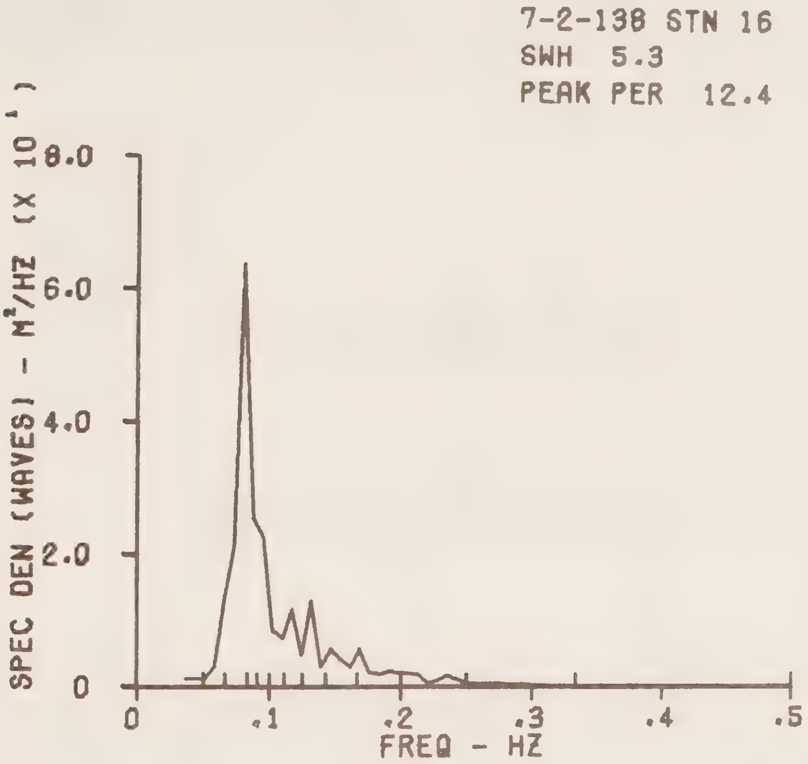

Fig. 8. Spectrum diagram.

If corrections were required for either instrument response or, in the case of a pressure cell, for the attenuation of the pressure fluctuations with depth they will have been applied to the spectrum.

The units of variance spectral density are meters squared per Hertz and the units of frequency are Hertz. The wave record can be identified by the record-side-tape number and the station number annotated in the upper right hand corner. The time of recording and other pertinent information must come from accompanying documentation. The abbreviations SWH and PEAK PER if they appear are followed by the significant wave height in meters and the peak period in seconds. The peak period is the inverse of the frequency at which the maximum spectral density occurred. The significant or characteristic wave height is four times the square root of the area under the spectrum.

The surface elevation trace shown in Figure 9 is available only for wave records produced by an instrument which does not require substantial frequency-dependent response corrections to the recorded sensor signal. For a pressure sensor the trace produced will be the pressure as a function of time.

For convenience the twenty-minute wave record has been broken up into four 300-second sections. The annotation under the end of the abscissa axis identifies the sections as ending at 300, 600, 900 and 1200 seconds. The annotations appearing between the vertical axes are the plus and minus values in meters (or psi for a pressure cell) corresponding to the maximum and minimum values of the ordinate axes. The position of the abscissa axis represents the mean of the record and is defined as the zero of the surface elevation or pressure trace.

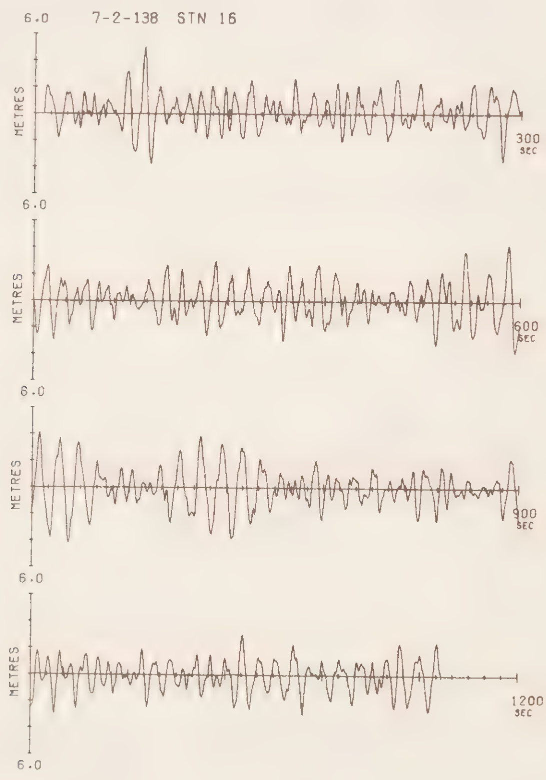

Fig. 9. Surface elevation trace.

The wave record is identified by the record-side-tape number and the station number annotated in the upper left hand corner of the diagram. The time of recording and other pertinent information must come from accompanying documentation.

The wave height listing (Table 1) has one line of print for each 20 minute wave record. The record, side and analog recording tape number and

Table 1. The wave height listing recorded off Logy Bay, Nfld.

STATION 16 WAVES RECORDED OFF LOGY BAY,NFLD. PAGE 1

ROOT MEAN SQUARE WAVE HEIGHT (METRES) TABULATED BY WAVE PERIOD

RECORD -SIDE -TAPE	OCT 1977 HOUR	-DAY	2.0 TO 3.0 SEC	3.0 TO 4.0 SEC	4.0 TO 5.0 SEC	5.0 TO 6.0 SEC	6.0 TO 7.0 SEC	7.0 TO 8.0 SEC	8.0 TO 9.0 SEC	9.0 TO 10.0 SEC	10.0 TO 11.0 SEC	11.0 TO 12.0 SEC	12.0 TO 13.0 SEC	13.0 TO 14.0 SEC	14.0 TO 15.0 SEC	15.0 TO 16.0 SEC	16.0 TO 20.0 SEC	CHAR WAVE HT IN M	PEAK PER. SEC.
5-1-130	100	1	.08	.11	.17	.21	.23	.30	.37	.46	.54	.45	.17	.09	.07	.05	.07	4.25	10.50
6-1-130	400	1	.12	.15	.16	.22	.20	.28	.30	.45	.40	.23	.11	.05	.04	.03	.03	3.46	9.75
7-1-130	700	1	.11	.16	.19	.17	.22	.27	.23	.34	.39	.28	.15	.08	.07	.05	.06	3.25	10.50
8-1-130	1000	1	.11	.15	.14	.16	.21	.21	.29	.26	.20	.22	.06	.05	.04	.03	.04	2.59	8.53
9-1-130	1300	1	.10	.12	.13	.14	.16	.17	.22	.29	.21	.17	.09	.03	.02	.02	.02	2.31	9.10
10-1-130	1600	1	.10	.12	.11	.12	.15	.18	.22	.24	.25	.10	.05	.04	.03	.02	.02	2.15	10.50
11-1-130	1900	1	.08	.10	.11	.12	.20	.21	.27	.22	.22	.10	.05	.04	.03	.03	.03	2.22	10.50
12-1-130	2200	1	.06	.09	.12	.12	.17	.20	.23	.19	.17	.08	.05	.03	.03	.03	.03	1.96	9.10
13-1-130	100	2	.05	.08	.11	.13	.16	.22	.24	.19	.14	.07	.04	.03	.02	.02	.03	1.93	8.53
14-1-130	400	2	.06	.07	.10	.12	.14	.17	.20	.17	.12	.06	.05	.03	.02	.02	.03	1.68	8.53
15-1-130	700	2	.05	.07	.09	.10	.12	.17	.24	.18	.11	.05	.03	.03	.02	.01	.02	1.68	8.53
16-1-130	1000	2	.04	.05	.08	.10	.14	.20	.24	.17	.09	.07	.03	.02	.02	.02	.02	1.69	9.10
17-1-130	1300	2	.05	.07	.08	.10	.13	.18	.18	.17	.11	.07	.04	.03	.03	.02	.02	1.60	9.75
18-1-130	1600	2	.07	.07	.08	.10	.13	.18	.20	.18	.17	.06	.03	.02	.02	.01	.02	1.71	9.10
19-1-130	1900	2	.08	.11	.08	.10	.13	.18	.15	.16	.13	.07	.03	.03	.02	.02	.02	1.59	9.75
20-1-130	2200	2	.09	.16	.17	.10	.10	.14	.14	.12	.12	.06	.03	.03	.02	.02	.02	1.60	8.03
21-1-130	100	3	.09	.13	.21	.13	.12	.15	.15	.17	.09	.05	.03	.03	.02	.02	.02	1.73	9.75
22-1-130	400	3	.10	.14	.20	.24	.13	.12	.13	.15	.09	.07	.04	.02	.02	.02	.02	1.86	5.69
23-1-130	700	3	.09	.13	.17	.27	.23	.16	.12	.10	.09	.05	.03	.03	.02	.02	.02	1.97	5.94
24-1-130	1000	3	.09	.12	.16	.25	.34	.20	.11	.12	.08	.05	.05	.04	.03	.02	.02	2.22	6.50
25-1-130	1300	3	.10	.17	.20	.24	.35	.28	.22	.15	.09	.08	.05	.04	.03	.02	.03	2.61	6.83
26-1-130	1600	3	.09	.14	.20	.20	.28	.36	.20	.13	.09	.09	.08	.04	.03	.03	.02	2.53	7.59
27-1-130	1900	3	.09	.13	.15	.19	.26	.42	.23	.10	.09	.10	.09	.05	.04	.03	.02	2.62	7.19
28-1-130	2200	3	.09	.14	.16	.17	.22	.31	.22	.12	.11	.15	.08	.04	.04	.04	.03	2.32	8.03
29-1-130	100	4	.08	.13	.15	.16	.26	.23	.16	.14	.11	.13	.11	.03	.02	.02	.02	2.15	6.83
30-1-130	400	4	.08	.14	.17	.18	.23	.27	.13	.08	.10	.10	.05	.04	.03	.03	.02	2.07	7.19
31-1-130	700	4	.09	.14	.15	.17	.19	.24	.13	.12	.11	.05	.05	.03	.03	.02	.02	1.90	7.19
32-1-130	1000	4	.08	.11	.16	.16	.22	.21	.13	.09	.11	.07	.04	.04	.03	.02	.02	1.82	7.19
33-1-130	1300	4	.08	.13	.14	.16	.21	.23	.11	.07	.10	.07	.03	.03	.03	.02	.02	1.83	7.19
34-1-130	1600	4	.09	.15	.15	.20	.26	.19	.10	.09	.10	.05	.05	.03	.02	.02	.03	1.93	6.21
35-1-130	1900	4	.09	.12	.15	.16	.24	.17	.10	.11	.08	.06	.03	.03	.02	.02	.02	1.77	6.21
36-1-130	2200	4	.09	.12	.15	.18	.17	.14	.13	.09	.07	.04	.04	.03	.03	.02	.02	1.61	5.94
1-2-130	100	5	.08	.12	.14	.15	.17	.13	.14	.10	.07	.04	.03	.03	.02	.01	.02	1.53	8.03
2-2-130	400	5	.07	.09	.13	.14	.18	.12	.10	.08	.06	.04	.04	.02	.02	.01	.01	1.39	6.83
3-2-130	700	5	.07	.09	.12	.14	.17	.15	.09	.11	.09	.05	.03	.03	.02	.01	.02	1.43	6.21
4-2-130	1000	5	.06	.09	.11	.16	.19	.17	.14	.13	.07	.05	.03	.03	.02	.01	.01	1.61	9.10
5-2-130	1300	5	.07	.09	.11	.17	.17	.20	.14	.11	.08	.05	.03	.03	.02	.01	.02	1.62	7.19
6-2-130	1600	5	.06	.08	.12	.16	.20	.22	.18	.11	.07	.04	.03	.02	.01	.01	.01	1.74	7.19
7-2-130	1900	5	.06	.08	.11	.16	.19	.26	.21	.14	.10	.05	.03	.03	.02	.02	.03	1.93	7.19
8-2-130	2200	5	.08	.09	.10	.14	.21	.27	.20	.13	.08	.06	.05	.03	.02	.02	.02	1.92	7.59
9-2-130	100	6	.08	.09	.13	.14	.18	.21	.26	.14	.10	.06	.04	.05	.03	.02	.02	1.93	8.03
10-2-130	400	6	.08	.09	.12	.17	.14	.24	.18	.16	.09	.05	.06	.05	.04	.02	.02	1.86	7.59
11-2-130	700	6	.08	.08	.11	.12	.15	.20	.22	.15	.08	.06	.08	.03	.03	.03	.02	1.77	8.03
12-2-130	1000	6	.07	.08	.11	.12	.15	.17	.17	.19	.09	.09	.09	.03	.03	.03	.04	1.71	9.10
13-2-130	1300	6	.07	.08	.09	.14	.15	.18	.20	.19	.12	.11	.09	.05	.04	.02	.02	1.84	9.10
14-2-130	1600	6	.07	.09	.10	.11	.17	.16	.18	.15	.13	.09	.10	.07	.05	.04	.04	1.73	8.03
15-2-130	1900	6	.06	.07	.08	.09	.12	.15	.17	.19	.13	.11	.14	.11	.06	.06	.05	1.79	9.75
16-2-130	2200	6	.06	.06	.07	.10	.13	.12	.15	.14	.12	.19	.20	.13	.08	.03	.05	1.85	12.41
17-2-130	100	7	.08	.06	.07	.08	.08	.12	.13	.13	.13	.15	.18	.09	.08	.06	.05	1.64	12.41

the time of recording is shown. The time is local standard or local daylight saving time, whichever is in effect.

The columns headed 2 to 3 sec, 3 to 4 sec etc., show rms wave heights in meters obtained by integrating under the variance spectrum of the water surface elevation to find the area between frequencies corresponding to the two periods appearing at the top of the column and taking the square root of the result.

The value in the column headed characteristic wave height is the significant or characteristic wave height which is computed as four times the square root of the area under the variance spectrum.

The column headed "peak per" is the inverse of the frequency at which the maximum spectral density occurred.

In addition to the standard data products, wave data is available on magnetic tape in digital form. Both computed spectral and surface elevation data are available in this manner. Other special processing of the wave sensor signals is carried out on an "ad hoc" basis. An example of this would be the regeneration of the water surface elevation trace from a pressure

sensor record. This is accomplished by Fourier transforming the record, correcting the Fourier amplitudes according to small amplitude wave theory and resynthesizing the components to produce the surface elevation trace.

6. SUMMARY

The study has operated since 1968 and has accumulated in excess of the order of 1500 months of wave climate data at approximated 200 locations with an 80 to 90 percent success rate at a given site.

The wave data file now consists of one set of magnetic tapes which contains digital surface elevation information and a second set of tapes containing wave spectrum information. There are in excess of 300,000 records in each of these files. Wave data are all available in the forms described in this report.

Significant benefits of the study lie in the area of better designed marine facilities because of the availability of high quality wave data. Worthy of note also is the fact that two scientists, one in the USA and the other in Spain have chosen to develop and test computerized hindcast models in Canadian waters because of the availability of these data.

The future of the study is seen as similar to the past unless some breakthrough in techniques results in remote sensed high quality wave data being available or until the collection of directional data is proven feasible.

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